

# **Towards Automated Scheduling of NASA's Deep Space Network: A Mixed Integer Linear Programming Approach**

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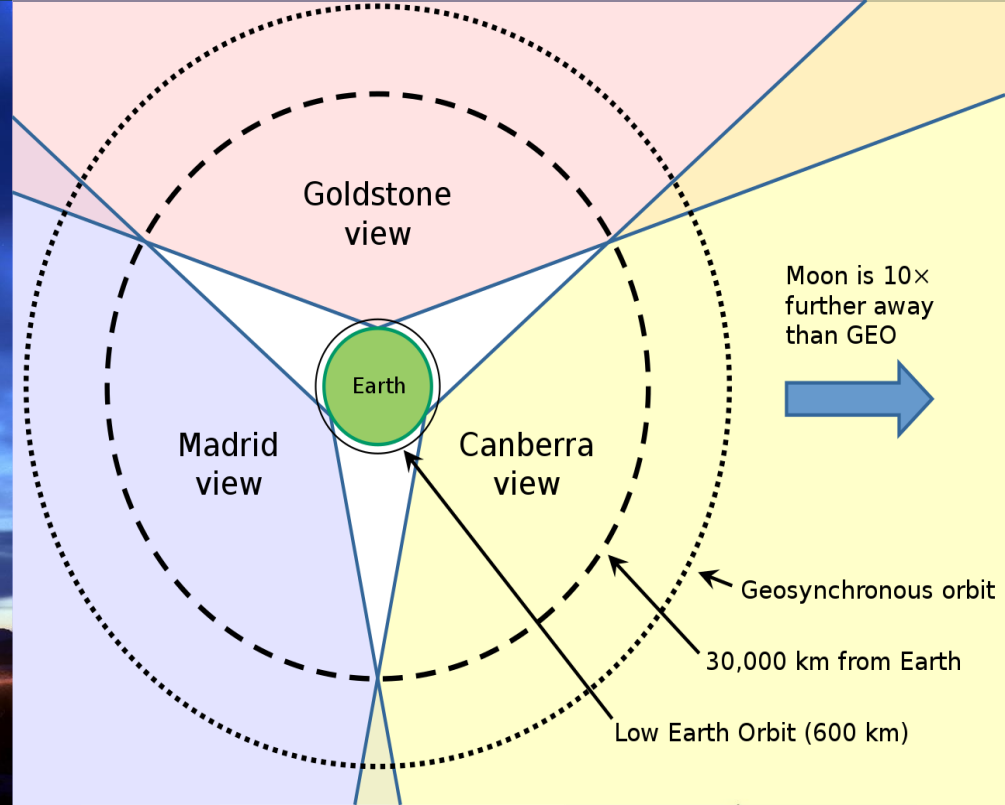
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# Outline

- NASA's Deep Space Network
- Deep Space Network Scheduling Problem
- Mixed Integer Linear Programming
- DSN as a MILP
- Experiments and Results
- Conclusion

# NASA's Deep Space Network



# NASA's Deep Space Network

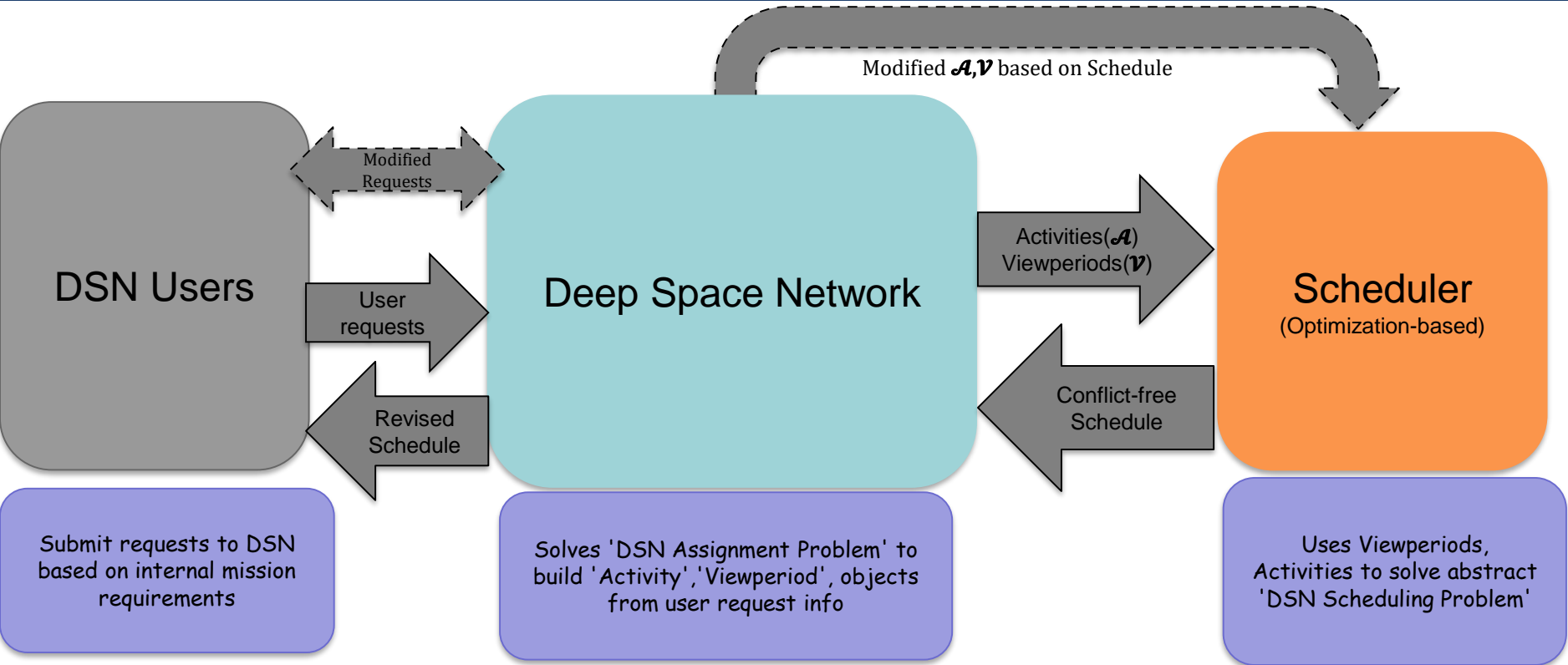


# NASA's Deep Space Network

- High demand for DSN resources
- Constraints makes resource allocation challenging



# Deep Space Network Scheduling



# Mixed Integer Linear Programming(MILP)

$$\begin{array}{ll}\min_{\mathbf{x}} & \mathbf{f}^T \mathbf{x} \\ \text{subject to:} & A_{in} \mathbf{x} \leq b_{in} \\ & A_{eq} \mathbf{x} = b_{eq} \\ & l \leq \mathbf{x} \leq u \\ & \mathbf{x} \in \mathbb{R} \\ & x_j \in \{0,1\} \text{ for some } j\end{array}$$

- Process Control
- Flight Path Planning
- Risk Portfolio Optimization
- Job Shop Scheduling

# DSN Scheduling as a MILP

## Important Constraints

1. Each resource can only support one activity at any given time.
2. Each activity can only be scheduled to one viewperiod at any given time.
3. If an activity is scheduled, its tracking time must occur within a valid viewperiod.
4. If an activity is scheduled, it must be scheduled for at least its minimum requested tracking time, and at most its maximum requested tracking time.
5. An activity requires a certain amount of setup time before tracking time can occur, and teardown time after.
- ~~6. Activities may be 'split', i.e. not scheduled contiguously.~~

# Problem Statement

Given a set of Resources( $\mathcal{R}$ ), Activities( $\mathcal{A}$ ), Viewperiods( $\mathcal{V}$ ), Time Epochs( $\mathcal{T}$ ), Constraints( $\mathcal{C}$ ), and Objective Function( $f$ )...

...what is the optimal schedule with respect to  $f$ ?

# DSN Scheduling: Objective Functions

Objective 1: Maximize the number of scheduled activities

$$\mathbf{f} = \sum_{i=1}^n x_i$$

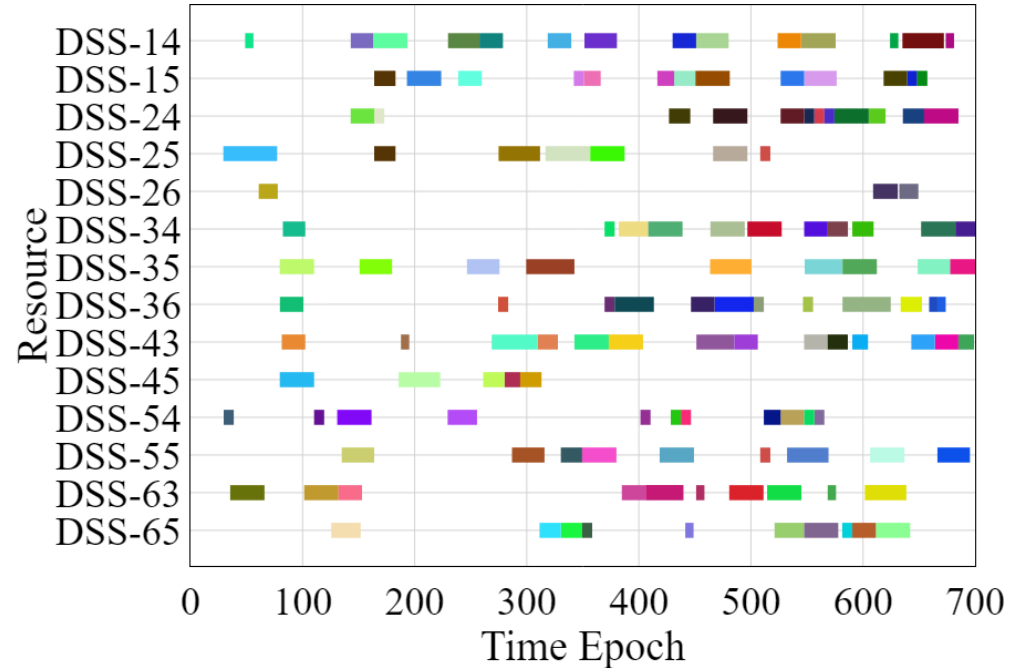
Objective 2: Maximize the amount of scheduled time

$$\mathbf{f} = \sum_{i=1}^n w_i x_i$$

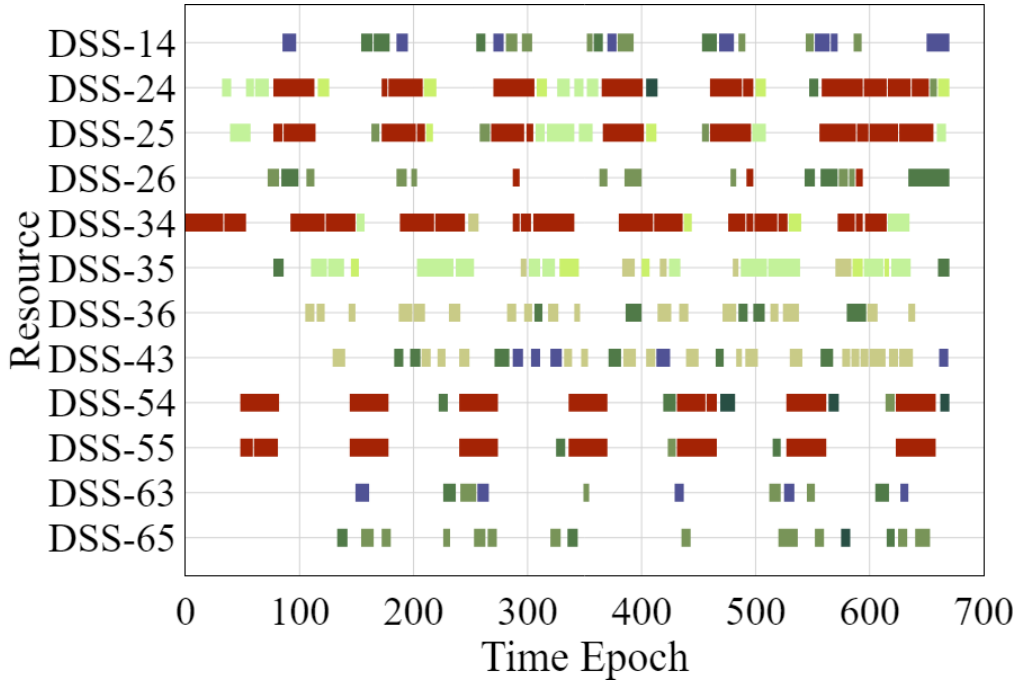
$$x_i = \begin{cases} 1, & \text{activity } i \text{ scheduled} \\ 0, & \text{o. w.} \end{cases}$$

# Experiments and Results

- Implemented using AMPL modeling language, GUROBI solver, python AMPL API
- 86 out of 95 activities scheduled on toy problem constructed from real-world data on Week 44, 2018



# Experiments and Results



- Result for Week 44, 2016.  
139 out of 286 activities  
scheduled
- Shows difficulty scaling up to  
full problem size

# Conclusion and Future Works

- Must address curse of dimensionality (scaling)
- Must incorporate the 'splitting' of activities into the model
- Must ensure user satisfaction by analyzing from DSN users' perspective

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